TWINNING IN CATTLE: III. EFFECTS OF TWINNING ON DYSTOCIA, REPRODUCTIVE TRAITS, CALF SURVIVAL, CALF GROWTH AND COW PRODUCTIVITY[1,2,3]

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ABSTRACT

An evaluation of natural twinning in beef cattle revealed that cows birthing twins had shorter ($P < .01$) gestation lengths, more ($P < .01$) retained placentas, more ($P < .01$) dystocia, more ($P < .01$) days to estrus, lower ($P < .01$) conception rates and more ($P < .01$) days to pregnancy than cows birthing singles. Days to estrus, conception rate and days to pregnancy were not affected by number of calves reared (1 vs 2) in cows birthing twins. Survival at birth was greater ($P < .01$) for single- than for twin-born calves, but twins and singles did not differ ($P > .05$) in postnatal survival. When dystocia was experienced, calf survival at birth was 95% vs 73% for singles vs twins compared with 99% vs 92% when no dystocia was experienced. Calves born twins were lighter ($P < .01$) at birth, 100 d and 200 d, but twins and singles did not differ in postweaning gains. Total calf weights at 100 d per cow calving were 12% greater ($P < .01$) in cows birthing twins vs singles when twin calves reared by foster dams were excluded. The potential increase in cow productivity for total calf weight at 100 d is 40% if calf survival rates of twins with dystocia relative to survival rates of twins without dystocia were comparable to survival rates of singles with and without dystocia, and if cows birthing twins were fed and managed to obtain conception rates equal to those of cows birthing singles. Identification of cows gestating twins to provide for their higher prepartum nutritive requirements and calving assistance at parturition is necessary to make twinning in cattle an economically viable technology. (Key Words: Cattle, Twinning, Calf Production, Dystocia, Survival, Reproductive Traits.)

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Introduction

Beef cattle have low biological efficiency. More than 50% of the feed units used by the beef herd of the U.S. are needed to meet requirements for maintenance of the reproducing female population; comparable requirements in meat-type chickens are about 3% (Gregory and Dickerson, 1989). High-producing dairy cows are capable of producing a unit of milk protein for about one-fifth the feed energy required to produce a unit of beef protein (Reid et al., 1980). Based on results from experimentation (twins produced by embryo transfer) and production system stimulation, assuming increased labor and veterinary costs of 40% per cow, the estimated increase in efficiency of producing beef through twinning was 24% when marketed at 400 d (Guerra-Martinez et al., 1990). Results of Gregory et al. (1990) and Echternkamp et al. (1990) suggest that there is potential for genetic improvement in twinning rate of cattle

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through selection, particularly when multiple observations of ovulation rate are a primary selection criterion for replacement females and selection of young sires is based on ovulation rate of daughters and sibs. Even though genetic improvement of twinning rate to a level that may make it economically feasible is promising, adjustments in management practices are required to exploit the full potential of twinning to increase efficiency of beef production. Problems associated with twinning may include increased dystocia, increased retention of placentas, lower calf survival, increased postpartum interval and decreased conception during the subsequent breeding season (Turman et al., 1971; Bellows et al., 1974; Johansson et al., 1974; Cady and Van Vleck, 1978; Anderson et al., 1979, 1982). Results have not been consistent for some of these traits. This paper reports results from a comprehensive experiment designed to assess the biological and economic feasibility of a high frequency of dizygotic twinning by selection with the objective of improving efficiency of beef production for intensive systems. The purpose of this study was to further identify and quantify some of the biological constraints that must be alleviated before a biologically and economically feasible twinning technology can be fully developed for beef cattle and to evaluate potential increases in cow productivity through twinning.

Materials and Methods

Data for this study were from a project, Twinning in Cattle, that was established at the U.S. Meat Animal Research Center (Gregory et al., 1988, 1990). Data were recorded on cattle subsequent to their transfer from other projects at the Research Center to the twinning project, by their progeny born in the twinning project and by progeny of purchased females born in the twinning project. Data on females purchased for this project because of their high rate of twinning were excluded from the study because of great variation in treatment prior to purchase. Breeds and their crosses that provided data included 1) Holstein, 2) Simmental, 3) Charolais, 4) Brown Swiss, 5) Braunvieh, 6) Pinzgauer, 7) Gelbvieh, 8) Swedish Friesian, 9) Norwegian Red, 10) Shorthorn, 11) Hereford and 12) Angus (Gregory et al., 1990).

Females in the twinning project calve in approximately equal numbers in spring and fall. Breeding seasons were about 45 d in virgin heifers and 60 d in females 2 yr old and older. Females were bred to calve first at either 2 or 2.5 yr of age; no distinction was made between 2 vs 2.5 yr in the analysis. For heifers, the spring breeding season was from late May until mid-July and fall breeding season was from late October until mid-December. For females 2 yr old and older, the spring breeding season lasted from mid-June until mid-August and the fall breeding season lasted from late October until late December. All virgin heifers (either 1 or 1.5 yr) were bred by natural service. Spring matings of females 2 yr old and older were by artificial insemination (40 d) followed by natural service (20 d) throughout the study. Fall matings were by natural service until 1985. Starting in 1985, fall matings were by a combination of artificial insemination (40 d) followed by natural service (20 d). Data on some reproductive traits were not recorded in the early years of the experiment.

Calves were weaned at an average age of 100 d, about midway through the breeding season (i.e., about 1 wk before the end of artificial insemination mating period). Early weaning was practiced to allow a post-lactation period of at least 3 wk during the mating season. Fall-born calves were offered feed (creep feeder) prior to weaning, but spring-born calves did not receive supplemental feed prior to weaning. Calves were fed a diet of 2.63 mcal ME/kg DM and 14.4% CP from weaning to 200 d. The experimental protocol was to cross-foster only if, in the judgment of support staff, there was high probability of losing a calf if both members of a set of twins were left on their dam. Data on days to estrus were not collected until 1985. Data on other traits were collected from 1981 through 1988. Because of small numbers in 1981 and 1982, data collected in these years were combined in the analyses. There were two sets of triplets. Triplets were included for analyses of traits of the dam but were excluded for analyses of traits of the calf.

No attempt was made to identify cows gestating twins and to feed and manage them according to their higher requirements. All cows were managed in a relatively favorable nutritive environment for cows producing singles. Cows birthing and rearing twins were separated and fed on a higher plane of nutrition subsequent to calving than cows birthing singles.

Data were analyzed by least squares fixed model procedures (Harvey, 1977). Unless a trait was included in a grouping of traits in which some of the two-way interactions were significant, nonsignificant two-way interactions were deleted from final analysis. Three-way interactions were assumed to be nonsignificant. The number of years from which data are included, the main effects and interactions included in the model used for analysis of each trait are indicated in Tables 1, 2, 3, 4 and 5. Least squares means for year of birth are not included in the tables. Data were analyzed for some traits with values presented in the text but not in tables. Also, values involving significant interactions are presented primarily in the text but not in tables.

Results

Reproductive Traits

Type of Birth. Length of gestation was 7 d shorter ($P < .01$) in cows birthing twins than in cows birthing singles (Table 1). Cows birthing twins had more retained placentas (21.5% vs 2.8%, $P < .01$) than cows birthing singles. Retained placentas were diagnosed in 45 of 209 cows birthing twins and in 53 of 1,879 cows birthing singles. Among cows that gave birth to twins, the effects of retained placentas on days to estrus, percentage observed in estrus and on days to pregnancy were not important ($P > .10$). The effect of retained placentas on conception rate approached significance ($P = .10$). The small number of observations for retained placentas (from 9 to 17 for different reproductive traits) suggests that caution should be exercised when interpreting these effects of retained placentas.

Among cows in which estrus was observed, days to estrus was longer ($P < .01$) in cows birthing twins than in cows birthing singles. Rate of estrus detection in the subsequent breeding season did not differ between cows birthing twins and cows birthing singles. Conception rate, based on cows calving relative to cows exposed, in the subsequent breeding season favored ($P < .01$) cows birthing singles (85% vs 71%). Among cows that conceived in the subsequent breeding season, days to pregnancy was shorter ($P < .01$) in cows birthing singles than in cows birthing twins. Days to estrus, percentage observed in estrus, conception rate and days to pregnancy in the subsequent breeding season were not affected by calves reared (1 vs 2) in cows birthing twins. Number reared (1 vs 2) in cows birthing twins did not affect postpartum reproduction when calves were weaned at 100 d.

Age of Cow. Gestation length was shorter in younger cows ($P < .01$; Table 1). The effects of age of cow were significant for days to estrus, percentage observed in estrus, and days to pregnancy but not conception rate ($P = .14$) in the subsequent breeding season. Three-year-old cows had more days to estrus and more days to pregnancy than 4-, 5- and 6+-yr-old cows. Four-year-old cows had a smaller percentage observed in estrus than 3-, 5- and 6+-yr-old cows (Table 1).

Season of Calving. Gestation length did not differ ($P > .05$) between spring- and fall-calving cows (Table 1). Days to estrus was longer ($P < .01$) among cows detected in estrus in spring-calving than in fall-calving cows (79 d vs 65 d); however, estrus was observed in a higher ($P < .01$) percentage (99% vs 92%) of spring-calving than of fall-calving cows. Conception rate favored ($P < .05$) spring-calving cows over fall-calving cows (79% vs 73%), but among those conceiving, fall calving and spring calving cows did not differ in days to pregnancy. The interaction of type of birth with season of birth was significant for percentage observed in estrus; cows birthing singles differed less between spring and fall than cows birthing twins. The interaction of age of cow with season of birth was significant for percentage observed in estrus and for days to pregnancy. Three-year-old cows differed more in percentage in which estrus was observed between spring and fall than 4-, 5- and 6+-yr-old cows. Days to pregnancy were greater in spring than in fall for 3- and 4-yr-old cows but were greater in fall than in spring for 5- and 6+-yr-old cows.

Years of Calving. The effects of year of calving were significant for gestation length, days to estrus, percentage observed in estrus and days to pregnancy but not for conception rate (Table 1).

Dystocia

Type of Birth. Type of birth had an important ($P < .01$) effect on dystocia (Table 2). The fraction requiring assistance was 35% for cows birthing twins vs 23% for cows

TABLE 1. SUMMARY OF *F* STATISTICS FROM ANALYSIS OF VARIANCE AND LEAST SQUARES MEANS FOR REPRODUCTIVE TRAITS

Item	df or no.	Gestation length, d	df or no.	Days to estrus	df or no.	Estrus observed, %	df or no.	Conception rate, %[a]	df or no.	Days to pregnancy[b]
Analysis of variance										
Type of birth (B)	1	138.1**	2	14.4**	2	1.2	2	7.4**	2	6.8**
Age of cow (A)	3	7.8**	3	29.9**	3	3.8**	3	1.8	3	17.0**
Season of calving (S)	1	.1	1	77.3**	1	10.2**	1	6.1**	1	.0
Year of calving (Y)	4	4.6**	3	2.6*	3	2.6*	3	1.6	3	8.3**
B × A					6	3.4**				
B × S					2	3.8**				
A × S					3	4.2**			6	2.2*
Residual mean square	883	26.2	933	524.7	1,132	282.3	1,143	1,465.6	927	506.0
Least squares means										
μ	893	282	943	72	1,153	96	1,153	76	943	92
Type of birth										
Single	790	286								
Twin	103	279								
11[c]			839	63	1,007	97	1,007	85	839	85
21			42	76	58	95	58	71	42	97
22			62	77	88	95	88	71	62	93
Cow age										
3 yr	320	281	342	84	429	91	429	71	342	100
4 yr	203	282	261	68	308	77	308	77	261	88
5 yr	145	283	134	68	162	94	162	78	134	89
6+ yr	225	283	206	68	254	100	254	76	206	88
Season of calving										
Spring	495	282	428	79	504	99	504	79	428	91
Fall	398	282	515	65	649	92	649	73	515	92

[a]Based on cows calving relative to cows exposed.

[b]Among cows that conceived.

[c]11 = born single, reared single; 21 = born twin, reared single; 22 = born twin, reared twin.

*≤ .05.

**≤ .01.

birthing singles with a comparable difference in dystocia score. Among twin births, 7.2% were classified as abnormal presentations, whereas, among singles, only 2.7% were classified as abnormal presentations.

Cow Age. The effects of cow age on dystocia were significant (Table 2). Two-year-old cows required assistance with about twice the frequency of 3-yr-old and older cows. Differences in dystocia among 4-, 5- and 6+-yr-old cows were small.

Season of Calving. Spring-calving cows required more ($P < .05$) assistance than fall-calving cows, but the difference was small (31% vs 27%; Table 2). The significant interaction of age of cow × season of birth was the result of a relatively large difference in dystocia in 2-yr-old cows between spring and fall parturitions (61% vs 46%). This difference accounted for most of the effect of season on dystocia. The mean difference in dystocia between spring- and fall-calving cows was only 1% for 3-, 4-, 5- and 6+-yr old cows.

Year of Calving. The effects of year of calving on dystocia were significant but did not follow a consistent pattern, and neither did the significant interaction of year of calving with type of birth (Table 2).

Calf Survival

Type of Birth. The effects of type of birth on calf survival were important ($P < .01$) at birth, 72 h, 100 d and 200 d (Table 3). Survival for calves born singles was greater than for calves born twins by 15%, 17%, 16% and 16% at birth, 72 h, 100 d and 200 d, respectively. Thus, differences in postnatal survival to 200 d were small (92% vs 89%) between twins and singles.

TABLE 2. SUMMARY OF *F* STATISTICS FROM ANALYSIS OF VARIANCE AND LEAST SQUARES MEANS FOR DYSTOCIA AS TRAIT OF DAM

Item	df or no.	Dystocia score[a]	Fraction requiring assistance
Analysis of variance			
Type of birth (B)	1	24.8**	15.1**
Cow age (A)	4	52.3**	68.7**
Season of calving (S)	1	7.4**	5.4*
Year of calving (Y)	6	7.2**	6.2**
B × Y	6	2.1*	2.3*
A × S	4	4.9**	5.2**
Residual mean square	2,456	3.4	.1748
Least squares means			
μ	2,479	2.2	.29
Type of birth			
Single	2,214	1.9	.23
Twin	265	2.6	.35
Cow age			
2 yr	755	3.2	.54
3 yr	550	2.2	.27
4 yr	379	1.8	.19
5 yr	287	2.0	.23
6+ yr	508	2.0	.22
Season of calving			
Spring	1,253	2.4	.31
Fall	1,226	2.1	.27

[a]1 = no difficulty, 2 = little difficulty by hand, 3 = little difficulty with calf jack, 4 = slight difficulty, 5 = moderate difficulty, 6 = major difficulty, 7 = caesarean birth and 8 = abnormal presentation.

*≤ .05.

**≤ .01.

The effects of gestation length (d) on survival at birth and 72 h were analyzed on data available for 101 sets of twins (202 calves). The model included age of dam, season of birth, year of birth and sex of calf as main effects. Gestation length (linear and quadratic) was included in the model as a covariate. None of the main effects was significant. The quadratic regression of calf survival on gestation length was important ($P < .01$). Tabulation of results revealed that survival at birth and 72 h was reduced when gestation length was less than 272 d. Summary of survival rates at birth and 72 h, respectively, by 4-d increments were as follows: < 272 d, 78% and 57%; 276 d, 95% and 83%; 280 d, 96% and 94%; 284 d, 84% and 84% and > 288 d, 93% and 93%. Similarly for calves born singles (790 observations), survival was reduced when gestation length was less than 272 d (62% and 50% at birth and 72 h, respectively). Survival among singles at birth and at 72 h was 97% or greater for all other classes of gestation length by 4-d increments > 272 d to > 292 d. Gestation length for twins ranged from 256 d to 291 d and for singles ranged from 258 d to 300 d.

Dystocia. As a trait of the calf, 72.2% of singles were born with no assistance or with minor hand assistance, 4.3% were born by caesarean section, 2.7% were abnormal presentations and 20.8% had dystocia scores of from 3 through 6 (Table 3). For calves born twins, 72.5% were born with no assistance or with minor hand assistance, 2.6% were born by caesarean section, 17.4% were abnormal presentations and 7.5% had dystocia scores of from 3 through 6. This included 2,214 calves born singles and 530 calves born twins. Thus, a major difference between twin and single born calves was in abnormal presentations. Calves that required repositioning of any type were classified as abnormal presentations.

The effects of dystocia (no assistance vs assistance) on calf survival were important ($P < .01$) at birth, 72 h, 100 d and 200 d. Survival of calves with no dystocia was higher by 11%, 13%, 14% and 14% at birth, 72 h, 100 d and

TABLE 3. SUMMARY OF *F* STATISTICS FROM ANALYSIS OF VARIANCE AND LEAST SQUARES MEANS FOR CALF SURVIVAL

Item	df or no.	Survival: Birth	72 h	100 d	200 d
Analysis of variance					
Type of birth (B)	1	178.5**	139.8**	93.6**	77.0**
Dystocia (D)	1	114.2**	88.6**	57.9**	51.1**
Cow age (A)	4	6.9**	4.9**	3.2**	1.9
Season of birth (S)	1	9.8**	4.6*	.8	.3
Year of birth (Y)	6	.8	1.3	4.6**	4.7**
Sex of calf	1	.7	1.2	1.5	1.8
B × A	4	4.7**	3.9**	1.8	.4
B × S	1	6.4**	1.3	.2	.5
B × D	1	44.8**	25.5**	14.3**	11.7**
Residual mean square	2,723	.0374	.0559	.0924	.1042
Least squares means					
μ	2,744	.90	.87	.82	.81
Type of birth					
Single	2,214	.97	.95	.90	.89
Twin	530	.82	.78	.74	.73
Dystocia					
No assistance	1,982	.95	.93	.89	.88
Assistance	762	.84	.80	.75	.74
Cow age					
2 yr	808	.86	.83	.80	.80
3 yr	613	.88	.84	.81	.80
4 yr	420	.90	.88	.82	.81
5 yr	333	.94	.91	.87	.85
6+ yr	570	.90	.86	.79	.78
Season					
Spring	1,354	.91	.88	.81	.80
Fall	1,390	.88	.85	.83	.81
Sex of calf					
Male	1,408	.89	.86	.81	.80
Female	1,336	.90	.87	.83	.82
Interaction					
B × D 1[a] 1[b]	1,598	.99	.98	.94	.92
1 2	616	.95	.92	.87	.86
2 1	384	.92	.88	.83	.82
2 2	146	.73	.68	.64	.63

[a]1 = single, 2 = twin.

[b]1 = no assistance, 2 = assistance.

*≤ .05.

**≤ .01.

200 d, respectively, than when assistance was required. The interaction of dystocia with type of birth was important ($P < .01$). The effect of dystocia on calf survival was considerably greater in twin than in single births; the differences in survival between calves experiencing dystocia and those with no dystocia at birth, 72 h, 100 d and 200 d were 19%, 20%, 19% and 19%, respectively, for twin births, compared with 4%, 6%, 7% and 6% for single births. Effects of dystocia on survival either in twins or in singles were fully expressed at birth and did not increase at subsequent ages.

Cow Age. The effects of cow age on calf survival were significant at birth, 72 h and 100 d but not at 200 d (Table 3). Calf survival to 200 d tended to be relatively higher in 5-yr-olds than in either older or younger cows. The significant interaction of cow age with type of birth on calf survival at birth and at 72 h was the result of relatively lower survival of twins than of singles out of young cows (75% for twins vs 96% for singles at birth and 73% for twins vs 93% for singles at 72 h out of 2-yr-old cows). For 5-yr-old cows, comparable values were 90% for twins vs 98% for singles at birth and 88% for twins vs 95% for singles at 72 h.

Season of Birth. The significant interaction between season of birth and type of birth was a result of no difference in survival at birth between spring- and fall-born singles (both 97%) but a difference between twins in spring (85%) and fall (79%) in survival at birth (Table 3). The cause of lower survival at birth in fall-born twins may be the result of a greater in utero (threshold) effect of environmental (heat) stress on dams of twins than on dams of singles in fall-born calves. Fall calves were born in August and September.

Year of Birth. The effects of year of birth were significant on survival at 100 d and 200 d but were not significant on survival at birth and at 72 h (Table 3). These significant year effects on survival at 100 d and 200 d were the result of a severe storm about midway through calving in the spring of 1987. Although not shown in Table 3, the interaction of year of birth with season of birth was significant for survival to 100 d and 200 d because of the effect of this storm.

Sex of Calf. The effects of sex of calf on survival were not significant (Table 3). However, survival favored females at all ages.

Growth Traits

Type of Birth. Effects of type of birth were important ($P < .01$) for all growth traits except average daily gain (ADG) from 100 to 200 d (Table 4). Calves born singles were approximately 10 kg heavier at birth than calves born twins.

Subsequent to adjustment of birth weight for differences between twins and singles in gestation length by including gestation length (d) in a model as a covariate (linear), birth weight of singles was 45.4 kg and of twins was 38.1 kg at a gestation length of 284 d. The regression of birth weight on gestation length (d) was similar (.54) kg for singles and (.53 kg) for twins ($P > .05$).

Calves born twins but reared singles had lower ($P < .05$) ADG to 100 d (i.e., weaning) and weighed less ($P < .05$) at 100 and 200 d than calves born and reared singles, but they had higher ($P < .05$) ADG to 100 d and heavier ($P < .05$) 100- and 200-d weights than calves born and reared twins. The three classes of birth and rearing did not differ ($P > .05$) in ADG from 100 d to 200 d (i.e., postweaning). Calves born twins but reared singles were the result of loss of a member of a twin set because of death or because of fostering one member of a set of twins by a cow that lost her calf.

Cow Age. The effects of cow age were important ($P < .01$) for all growth traits (Table 4). Except for the lighter birth and 100-d weights and lower preweaning gains (100 d) of calves with 2-yr-old dams, the effects of age of dam were small. Calves with 2-yr-old dams had higher ($P < .01$) ADG from 100 to 200 d (i.e., postweaning) than calves with older dams, suggestive of compensatory gain, and thus approached 200-d weight of calves with older dams.

Season of Birth. Effects of season of birth on birth weight were not significant (Table 4). In other populations at the Research Center, where both spring and fall calves are produced, fall-born calves generally have lighter birth weights than spring-born calves (Gordon Hays, personal communication). Spring-born calves gained significantly faster than fall-born calves from birth to 100 d and from 100 d to 200 d and were heavier ($P < .01$) at 100 d and at 200 d. The interaction of season of birth with age of cow was significant for all growth traits except postweaning gain (ADG from 100 d to 200 d) because the magnitude of the difference between spring- and fall-born calves tended to be greater in progeny of 2- and 3-yr-old cows than in progeny of older cows.

Sex of Calf. Male calves were heavier and grew faster (8 to 11%) than female calves ($P < .01$; Table 4).

Year of Birth. Effects of year of birth were significant for all growth traits, but followed no consistent pattern (Table 4).

Cow Productivity

Analyses for effects of type of birth and environmental factors on total calf weight per cow calving at 100 d and 200 d are presented in Table 5. Cow productivity for 100-d and 200-d weight of progeny was evaluated for three situations: 1) if a cow produced twins and one member was reared by a foster dam whose calf had diet, the natural dam was

TABLE 4. SUMMARY OF *F* STATISTICS FROM ANALYSIS OF VARIANCE AND LEAST SQUARES MEANS FOR GROWTH TRAITS

Item	df or no.	Birth[a] wt, kg	df or no.	Birth wt, kg[b]	100-d wt, kg[b]	200-d wt, kg[b]	ADG, birth to 100 d, g	ADG, 100 to 200 d, g
Analysis of variance								
Type of birth (B)	1	1,204.1**	2	446.9**	335.5**	126.9**	168.8**	2.6
Cow age (A)	4	68.1**	4	68.4**	52.7**	6.7**	26.4**	11.5**
Season of birth (S)	1	.6	1	.1	77.5**	128.4**	97.8**	84.5**
Year of birth (Y)	6	22.9**	6	20.7**	28.3**	32.3**	25.4**	97.2**
Sex of calf	1	178.7**	1	156.6**	223.4**	267.7**	144.0**	129.0**
A × S	4	3.8**	4	3.1**	3.0*	2.6*	3.6**	1.1
Residual mean square	2,726	37.6	2,380	35.0	321.4	958.1	.026	.044
Least squares means								
μ	2,744	39.6	2,399[d]	38.2	130	220	918	900
Type of birth								
Single	2,214	44.8						
Twin	530	34.3						
11[c]			1,997	44.8	146	238	1,014	916
21			171	34.8	128	216	931	876
22			231	35.0	116	207	809	910
Cow age								
2 yr	808	36.1	695	34.6	120	215	858	949
3 yr	613	39.1	536	37.9	130	218	916	888
4 yr	420	40.7	373	39.2	134	222	945	879
5 yr	333	41.3	304	39.8	135	226	955	909
6+ yr	570	40.5	491	39.4	131	219	916	877
Season								
Spring	1,354	39.4	1,181	38.2	134	228	954	944
Fall	1,390	39.7	1,218	38.2	126	212	882	857
Sex of calf								
Male	1,408	41.1	1,210	39.7	136	230	958	949
Female	1,336	38.0	1,189	36.7	124	210	878	852

[a]All calves born.

[b]Calves that survived to 200 d.

[c]11 = born single, reared single (100 d); 21 = born twin, reared single (100 d); 22 = born twin, reared twin (100 d).

[d]Calves alive at 200 d.

*≤ .05.

**≤ .01.

credited with the total production; 2) the natural dam was included and given credit only for the single calf she reared when a second calf was reared by a foster dam and 3) if one member of a twin set was reared by a foster dam, the natural dam and her entire record were excluded from the analysis. The rationale was that, in practice, the first procedure would be used when a single-calving foster dam was available that had lost her calf. The results from this practice provide one basis for evaluating differences in economic efficiency between twins and singles. The second procedure assumes that the second calf would have died if it were not reared by a foster dam. The third procedure provides a basis for evaluating differences in biological efficiency between cows birthing twins and cows birthing singles. Differences between twins and singles in calf survival are included in all procedures because results are based on all cows that calved. In each case, comparison was with own single calf from all cows calving singles. Information is provided on calf weight per cow calving at 200 d even though calves were weaned at an average age of 100 d. This is because 200 d approximates the weaning age for many beef calves in the U.S. Further, this information may be of interest to scientists evaluating the effects of twinning on differences in life cycle production efficiency. Information on 200-d weight per cow calving has greater value for this purpose than 100-d weight per cow calving.

TABLE 5. SUMMARY OF *F* STATISTICS FROM ANALYSIS OF VARIANCE AND LEAST SQUARES MEANS FOR CALF WEIGHT PRODUCED PER COW CALVING

Item	df or no.	100-d wt, kg[a]	200-d wt, kg[a]	100-d wt, kg[b]	200-d wt, kg[b]	df or no.	100-d wt, kg[c]	200-d wt, kg[c]
Analysis of variance								
Type of birth (B)	1	218.7**	281.5**	20.8**	43.0**	1	35.2**	55.2**
Cow age (A)	4	15.8**	9.2**	18.0**	10.5**	4	14.9**	8.6**
Season of birth (S)	1	8.6**	11.1**	.5	1.1	1	4.8*	5.4*
Year of birth (Y)	6	12.0**	12.2**	25.0**	13.5**	6	20.9**	12.7**
B × A	4	4.1**	4.1**	5.0**	5.4**	4	4.8**	4.5**
B × S	1	6.5**	3.0	.1	.3	1	3.4	.8
B × Y	6	5.5**	5.4**	15.5**	14.3**	6	13.2**	11.8**
Residual mean square	2,455	2,314.2	7,224.6	2,255.7	7,013.4	2,387	2,175.9	6,809.2
Least squares means								
μ	2,479	163	272	145	239	2,411	150	249
Type of birth								
Single	2,214	136	218	136	218	2,214	136	218
Twin	265	191	327	153	260	197	164	280
Cow age								
2 yr	755	141	244	119	206	740	126	217
3 yr	550	161	267	144	236	537	146	242
4 yr	379	170	280	154	251	370	156	256
5 yr	287	183	301	161	264	271	172	281
6+ yr	508	161	268	144	237	493	151	248
Season								
Spring	1,253	168	282	146	242	1,216	154	257
Fall	1,226	158	262	143	236	1,195	146	241

[a]Includes twin calves reared by foster dams.

[b]Includes record of natural dam if one calf reared by foster dam with credit given only for single calf reared by natural dam. Cow count same as in groups marked by footnote a but omits 68 calves reared by foster dams.

[c]Excludes record of dam if one calf was reared by foster dam.

*≤ .05.

**≤ .01.

Type of Birth. Effects of type of birth on production of calf weight at 100 d and 200 d were significant for each measure of productivity (Table 5). When 26% of the twin calves were reared by foster dams, calf weights at 100 d and 200 d were, respectively, 40% and 50% greater than calf weight produced by cows birthing and rearing singles. When natural dams reared only one member of their twin set and were given credit only for the calves they reared, total calf weight at 100 d and 200 d in cows birthing twins were, respectively, 12% and 19% greater than calf weight produced by cows birthing singles. When twin-birthing cows that had one calf reared by a foster dam were excluded from consideration, calf weight at 100 d and 200 d in cows birthing twins were, respectively, 20% and 28% greater than calf weight produced by cows birthing singles.

Cow Age. The effects of cow age and the interaction of cow age with type of birth were important ($P < .01$) on calf weight produced at both 100 d and 200 d in the three rearing situations (Table 5). The significant interaction was the result of a relatively small difference in weight produced per cow calving between twin- and single-birthing young cows, primarily because of the relatively lower survival of twin-born calves with 2- and 3- and 6+-yr-old dams. Weight produced at 100 d and 200 d increased through 5 yr of age but decreased for cows 6 yr and older.

Season of Birth. Effects of season of birth were significant for 100-d and 200-d weight produced per cow in the first and third but not in the second rearing situation (Table 5). Calf weights produced per cow to both 100 d and 200 d were greater for spring- than for fall-calving cows. The significant interaction between season of birth and type of birth for weight produced at 100 d, including the 26% of the twin calves reared by foster dams, is the result of no difference between spring- and fall-born singles but a large difference in favor of spring-born twins.

Year of Birth. Effects of year of birth and the interaction of year of birth with type of birth were important ($P < .01$) on calf weight produced at 100 d and 200 d in the three rearing situations (Table 5). Differences among years were small for singles but were relatively large for twins. A generally positive time trend in 100-d and 200-d weight observed for twins is interpreted to result from general improvements in husbandry required for twins, particularly for survival.

Discussion

Results presented by Gregory et al. (1990) and Echternkamp et al. (1990) suggest that there is potential to increase twinning rate in cattle by selection, particularly when multiple observations of ovulation rate in puberal heifers is a primary selection criterion for replacement females and young sires are selected based on ovulation rate of their daughters and sibs. Results from this study document further some major constraints that must be alleviated before the potential of twinning can be exploited as a production technology to reduce costs of beef production even if a high twinning rate can be achieved. Constraints on reproduction include increased dystocia, reduced calf survival at birth and reduced rebreeding performance of cows that give birth to twins.

The low reproduction rate of cattle and their relatively low biological efficiency in converting feed units into beef protein relative to converting feed units into milk protein by high-producing dairy cows (Reid et al., 1980) emphasizes their low biological efficiency and the limitations of beef cattle as competitors with dairy cattle or with litter-bearing meat animal species for use of high-value production resources. Results based on experimentation with embryo transfer twinning and production system simulation (Guerra-Martinez et al., 1990) suggest that production of twins could reduce beef production costs by about 24% even when a 40% increase in labor and veterinary costs is assumed for producing twins relative to singles.

In the current study, cows that twinned produced 40% more total calf weight at 100 d than single births when twin calves (26%) reared by foster dams to an age of 100 d were included; 20% more calf weight at 100 d when cows birthing twins that had one calf reared by a foster dam were excluded from consideration, and 12% more calf weight at 100 d when the natural dam was included and given credit only for the single calf she reared. If twinning is at a high frequency and rate of survival is high, the opportunity to use foster dams is limited. Thus, excluding foster dams in computing differences in cow productivity perhaps is the more realistic assumption because high twinning and survival rates seem necessary to make twinning in cattle an economically viable technology. Guerra-Martinez et al. (1990) reported 50% to 60% greater weaned calf weight per cow birthing embryo transfer twins vs singles.

If survival rate of twins to 100 d with dystocia (.64) and without dystocia (.83) were comparable to survival rate of singles to 100 d with (.87) and without (.94) dystocia (Table 3), the potential increase in cow productivity for total calf weight at 100 d is 40%. This potential increase was estimated from weighted distribution of twins and singles with dystocia (28% of calves at 77% survival for twins and 87% survival for singles), and without dystocia (72% of calves at 83% survival for twins and 94% survival for singles) from Table 3 and individual calf weight at 100 d (146 kg vs 116 kg from Table 4). This assumes that cows birthing twins can be fed and managed so that their subsequent conception rate is equal to that of cows birthing singles. Thus, a high twinning rate with high calf survival at birth and higher breeding efficiency has potential to increase beef production efficiency by spreading the high percentage (i.e., 50%) of total nutrients presently required for maintaining reproducing females over a greater calf output.

Results indicate that postnatal survival and postweaning gains are not different between calves born and reared twins vs calves born and reared singles. Thus, when multiple births are achieved, a high neonatal survival rate is required to optimize the impact of a twinning technology on beef production efficiency.

Results from the current study indicate that improved management practices to reduce dystocia, increase calf survival at birth and improve rebreeding performance must be developed and implemented to achieve the full potential of twinning as a production technology to reduce beef production costs. This, of course, assumes that twinning rate can be increased by selection or by nongenetic procedures. Per-cow costs of implementing some of these practices may be dependent on increased twinning frequency. The principle relates to the economies of scale; the number of cows producing twins must be sufficiently large to utilize fully the increased resources, particularly labor, needed to achieve high survival of twins at birth.

The effects of pre- and postpartum plane of nutrition on postpartum interval and on conception have been documented (Wiltbank et al., 1962). Thus, it is essential that a diagnostic procedure be developed to identify cows gestating twins so that they can be fed consistent with their higher nutritive requirement during the last trimester of gestation (Koong et al., 1982) and from parturition to conception.

The lack of difference in cows birthing twins between those rearing singles and those rearing twins in days to estrus, percentage observed in estrus, conception rate and days to pregnancy in the subsequent breeding season is of interest. These results suggest that meeting the high prepartum nutritive requirement of cows gestating twins (Koong et al., 1982) is necessary to achieve satisfactory postpartum reproduction. Number reared (1 vs 2) in cows birthing twins did not affect postpartum reproduction when calves were weaned at 100 d.

The effect of type of birth on survival at birth is of major importance; the results suggest that much of this effect is through dystocia (Table 3). The interaction of type of birth with dystocia on survival at birth suggests that primary attention should focus on reducing dystocia-related stress in twin births. Based on unrecorded observations by operations staff, cows birthing twins generally are less overt in signaling approaching parturition. Observations in this experimental population indicate that delay in providing assistance in twin births may be a major contributor to the low survival at birth (73%) of twins when dystocia is experienced. Survival of twins at birth was 92% when assistance was not needed, only 7% less than single births without dystocia (Table 3). Thus, these results suggest that a higher priority should be placed on early recognition of need for assistance and immediate response in rendering assistance in twin births.

Records of survival rate by order of birth were not maintained for twin births. However, impressions of operations staff were that survival rate of the second-born was lower than survival rate of first-born among twins requiring assistance. This may be expected unless the second-born is delivered immediately because of a reduction in oxygen supply as a result of the high percentage (~90%) of placental anastomosis observed in twins. This observation is based on the percentage of sterile heifers born twin to a bull because of failure of reproductive organs to develop. Thus, immediate delivery of the second-born seems essential if high survival rate among twins requiring assistance is to be achieved.

Early identification of cows gestating twins by ultrasonography will enable us to provide the higher nutritive requirements in the last trimester of gestation and the higher assistance requirement at parturition. Also, ultrasound may provide a tool for evaluating differences in second-phase embryonic/fetal loss that may occur (Echternkamp et al., 1990).

Implications

Calf weight per cow calving can be increased by 40% at 100 d through twinning. Major constraints must be alleviated before the potential of twinning can be realized as a new production technology to reduce costs of beef production even if a high twinning rate can be achieved. Constraints include increased dystocia, reduced calf survival at birth and reduced rebreeding performance of cows that give birth to twins. Alleviation of these constraints will require the early identification of cows gestating twins in order to provide for their higher nutritive requirements in the last trimester of gestation and for their higher assistance requirements at parturition. Ultrasound holds promise for determining number of embryos/fetuses between d 30 and d 75 of gestation.

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